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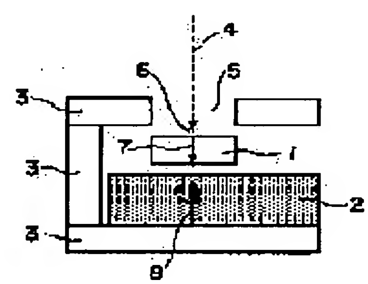
(54) MANUFACTURE OF MAGNET ARRAY AND LIGHT SOURCE USING THE SAME

(57)Abstract:
PURPOSE: To miniaturize a light source by periodically radiating a rare earth element magnet plate spatially at a predetermined interval with a radioactive ray to demagnetize while applying a reverse magnetic field to the magnet plate unidirectionally magnetized in a thickness direction, and simultaneously applying the reverse magnetic field to invert the magnetization.
CONSTITUTION: A permanent magnet magnetic circuit for applying a reverse magnetic field made of a permanent magnet 2 and a yoke 3 is manufactured, and a magnetized rare earth element permanent magnet plate 1 is inserted into an air gap 6. An electron beam 4 is radiated from an upper direction, and radiated to the plate 1 from a gap 5. Thus, a reverse magnetic field is generated in the plate 1 unidirectionally magnetized in the thickness direction, and the magnetization of the radiated site is inverted. Thus, the short period length of the magnet array in which the magnets periodically inverted in the magnetizing direction of the magnets can be realized without forming a thin plate magnet.



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(54)【発明の名称】　磁石列の製造方法と該磁石列を用いた挿入光源

(57)【要約】　（修正有）

【目的】　小型の挿入光源の作製。

【構成】　個々の磁石の磁化方向が周期的に反転する磁石を配列してなる磁石列の製造方法において、厚み方向に一方向磁化された希土類永久磁石板に逆方向磁場を印加しつつ、該磁石板に放射線を空間的に一定間隔で周期的に照射し該磁石板の照射部位を減磁し、同時に逆磁場を印加し磁化反転させることより成る磁石列の製造方法、及び該磁石列を用いてなる挿入光源。

【特許請求の範囲】

【請求項１】　個々の磁石の磁化方向が周期的に反転する磁石を配列してなる磁石列の製造方法において、厚み方向に一方向磁化された希土類永久磁石板に逆方向磁場を印加しつつ、該磁石板に放射線を空間的に一定間隔で周期的に照射し該磁石板の照射部位を減磁し、同時に逆磁場を印加し磁化反転させることを特徴とする磁石列の製造方法。

【請求項２】　放射線が電子線である請求項１に記載の磁石列の製造方法。

【請求項３】　逆方向磁場の印加が NdFeB磁石を用いて１テスラ以上で行う請求項１又は２のいずれかに記載の磁石列の製造方法。

【請求項４】　個々の磁石の磁化方向が周期的に反転する磁石を配列してなる磁石列を対向して配置し、該磁石列間に粒子線の通過のための空隙を設けてなる挿入光源において、請求項１～３のいずれかの方法で製造された磁石列を用いてなることを特徴とする挿入光源。

【請求項５】　磁石列の磁化方向の反転の周期長が５mm以下である請求項４に記載の挿入光源。

【請求項６】　該磁石列が真空下に配置されてなる請求項４又は５のいずれかに記載の挿入光源。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は磁石列の製造方法及び該磁石列を用いてなる挿入光源に関するものである。

【０００２】

【従来の技術】永久磁石または永久磁石と磁性材（鉄や鉄コバルト合金）で構成される挿入光源は、電子加速器（または電子蓄積リング）の直線部分に真空チャンバーを挟む形で挿入され、磁石列間の空隙中にサイン状の周期磁場を発生する（図１参照）。加速器中を回る高速電子は、該周期磁場により蛇行運動を行い、各蛇行点から放射光を生じる（Halbach, Nuclear Instruments and Method 187,(1981),109）。

【０００３】蛇行の程度によりウィグラーモードとアンジュレーターモードがある。ウィグラーモードでは各蛇行点から発生する放射光が重畳され、偏向電磁石よりの放射光より10倍～ 1,000倍高いパワーの放射光が得られる。これに対してアンジュレーターモードでは、各蛇行運動より発生する放射光は干渉し、基本波とその高次光ではウィグラー光の更に10～ 1,000倍程度強力な光が得られる。ウィグラーモードかアンジュレーターモードかは、Ｋ値と呼ばれるパラメーターにより分類できる。Ｋ値が１前後かそれ以下の場合はアンジュレーターとなり、それ以上のＫ値ではウィグラーとなる。

【０００４】挿入光源による放射光パワーは、磁石周期数に比例するためできるだけ周期数の大きな挿入光源が望ましく、そのためには、挿入光源を設置する電子加速器の直線部を長くする必要があるため、加速器を大きくする必要があるので、技術面やコスト面で限界がある。

【０００５】加速器を小さくするためには、挿入光源の周期長を短くする事が有効である。しかし、周期長を短くする場合、空隙長を同時に短くしなければならない。空隙長が大きい場合、図２に示すようにある磁極から出た磁束は、対向磁極方向（図２の点線）に向かわず、隣接磁極の方（図２の実線）に流れてしまうためである。周期長と空隙長の１つの目安は、周期長＝空隙長である。したがって、周期長が５mm以下の場合、空隙長も５mm以下程度にする必要がある。挿入光源の空隙間に入れる真空チャンバーをこのように狭くすると、インピーダンスが高くなり、必要真空度が達成できなくなったり、真空引きに長時間かかったりするようになる。

【０００６】短周期長の挿入光源を実現するため、真空封止型挿入光源が考案されている（Kitamura : Review of Scientific Instrument 63(1),(1992),400 ）。真空封止型では、１対の磁石列は真空チャンバー内に設置されるため、真空度達成の制約はなくなり、磁石空隙長を短くする事が可能となる。真空封止型の場合でも、幾らでも空隙長を短くできる訳ではない。阻害要因としては、電子のビーム径、真空系のインピーダンス、磁石磁気特性のばつらき、磁場計測方法や調整方法などが挙げられるが、特に永久磁石の磁気特性に関係する要因は重要である。

【０００７】

【発明が解決しようとする課題】挿入光源には、希土類磁石の焼結 NdFeB磁石が多く用いられ、このタイプの磁石は磁気特性が高く、着磁が容易である。したがって、空隙中に高磁場を発生するのに都合がよく、着磁による磁石間の特性のばらつきが少ないため、精密な磁場分布を実現するのに適している。このため挿入光源に一般的に使用されているが、短周期の挿入光源を実現する場合、問題が生じる。例えば、５mm以下の周期長の挿入光源を実現するためには、１mm前後の厚みを有する NdFeB磁石が必要である。

【０００８】NdFeB磁石では、薄肉の磁石の作製は、研磨加工や切断加工により実現されるが、加工により特性劣化を生じる。mmオーダー以上の肉厚の磁石では、面積／体積比が小さいため、加工劣化は殆ど問題にならないが、１mm以下の磁石では面積／体積比が大きくなり、相対的に表面積が大きくなるため、加工劣化が無視できなくなる。

【０００９】特に、挿入光源のように個々の磁石の磁気特性の均一性が必要な場合では、通常の磁気特性のばらつきに加えて、加工劣化による特性のばらつきが重畳されるため、深刻な問題である。薄肉 NdFeB磁石の加工劣化を緩和するため、磁石の熱処理や希土類金属被覆を磁石に施した後に熱処理を行う事が報告されているが、あまり有効ではない。

【００１０】

3

【課題を解決するための手段】本発明は短周期長の挿入光源を実現するため、NdFeB磁石の薄肉加工を行う事なく、着磁方法の改善により短周期長の磁石列を製造するものであり、これは、個々の磁石の磁化方向が周期的に反転する磁石を配列してなる磁石列の製造方法において、厚み方向に一方向磁化された希土類永久磁石板に逆方向磁場を印加しつつ、該磁石板に放射線を空間的に一定間隔で周期的に照射し該磁石板の照射部位を減磁し、同時に逆磁場を印加し磁化反転させることを特徴とする磁石列の製造方法及び、個々の磁石の磁化方向が周期的に反転する磁石を配列してなる磁石列の一対を対向して配置し、該磁石列間に粒子線の通過のための空隙を設けてなる挿入光源において、該磁石列を用いてなることを特徴とする挿入光源を要旨とするものである。

【0011】すなわち、厚み方向に一方向着磁された希土類永久磁石板を逆磁場を発生する磁気回路中に挿入し、これに放射線を照射することにより、照射部位の磁化を反転させる事ができるので、薄板磁石加工をすることなく個々の磁石の磁化方向を周期的に反転させた磁石を配列してなる磁石列の短周期長のものを実現する事ができることを見いだし、これにより、比較的短い長さで高周期数の挿入光源を作製でき、小型電子加速器に該挿入光源を用いる事により、強力な放射光を発生できることが判明し、種々検討して本発明を完成させた。

【0012】本発明は希土類永久磁石をmm単位以下の厚みに加工し、従来と同じように組み合わせて挿入光源を構成するのでなく、数周期分以上に相当する大きな磁石板を作製して、減磁、逆磁場着磁により周期的に磁化反転を形成する事により磁化方向を周期的に反転した小さな磁石を多数配列した磁石列を形成することができ、これを用いて挿入光源を作製するのが本発明の要点である。本発明の短周期長を有する挿入光源の実現のための技術の要点は2つあり、1つは一方向に一様に着磁した希土類永久磁石板を、放射線照射により一定間隔で周期的に減磁する点であり、もう1つは減磁した部所に逆磁場を印加して、磁化反転させる点である。

【0013】まず放射線照射による減磁について説明すると、希土類磁石は、ある種の放射線照射により減磁することが知られている。特に焼結NdFeB磁石や焼結1－5型SmCo磁石のような、核発生成長型の保磁力機構を有する希土類磁石は、焼結2－17型SmCo磁石に比較して、放射線照射により減磁しやすい事が知られている。この希土類磁石の減磁はどんな種類の放射線によっても起きるわけではなく、陽子、電子、中性子などの粒子線により起き易く、γ線やX線ではほとんど起きない。例えば本発明者らは、相対論的な高速電子線照射により生じるNdFeB磁石の減磁について報告した［日本放射光学会(1993年）で発表］。

【0014】電子線照射による減磁効果については、磁石の組織変化を伴うものではなく、また温度上昇による

4

熱減磁でもないことは明らかとなっているが、減磁の機構は明らかではない。定性的には図３（ａ）に示す消磁モデルが考えられる。すなわち、一定方向に磁化された磁石に電子線を照射するとその照射部位は図３（ｂ）（拡大図）に示すように互いに異なる方向に磁化されており、これが互いに打消し合って消磁されることが考えられる。このように磁石は電子線照射により組織変化などの永久劣化を起こしていないので、再着磁すれば元の磁束値まで回復する。

【0015】着磁された磁石板を部分的に減磁しようとする場合、熱印加による熱減磁では熱の拡散や熱膨張率の異方性による熱歪みのため、減磁領域の境界線がぼやけてしまったり、熱歪みによる割れのため、ある厚み以下の磁石板しか部分減磁できなかった。これに対して、放射線とりわけ電子線照射の場合、減磁は非熱的過程で起きるため、減磁領域と非減磁領域の境界は明瞭で、所望の領域のみ減磁することが可能である。もちろん、電子線照射によりある程度の温度上昇はあるが、照射量や磁石板の磁気特性、とりわけ保磁力を調整すれば、電子線照射領域のみ減磁させる事ができることが分かった。何故なら、高速電子は磁石内部まで浸透し、熱も表面から拡散するのではなく、照射部位では一様に発熱する事と、電子線照射は短時間パルスの繰り返し照射で与えられるので、実質的な照射時間は短く、温度上昇も80℃を越えることはないためである。電子線の位置制御は、磁場により精密に行えるので、短周期長の挿入光源で必要な１mm程度の間隔で電子線照射を行う事は容易である。

【0016】このように磁石の減磁を起こすに必要な電子線のエネルギー強度は１ＭｅＶ以上であればよく、好ましくは５～20ＭｅＶである。これが20ＭｅＶを超えると磁石材料の放射化の問題がある。

【0017】逆磁場印加は、電磁石、空心コイルによるパルス磁場や永久磁石を用いた磁気回路で出来るが、全体をコンパクトにできるNdFeB系永久磁石磁気回路が望ましい。例えば図４に示すように永久磁石２とヨーク３より成る逆磁場印加のための永久磁石磁気回路を作製し、空隙６に着磁希土類永久磁石板１を挿入する。上部方向より電子線４を照射し、隙間５より電子線４を該磁石板１に照射する。該磁石板か永久磁石磁気回路のどちらかを移動することにより、逆磁場印加の下で電子線照射を一定間隔で行う事が出来る。逆磁場を印加する永久磁石磁気回路において、空隙６に発生する磁場強度は、１テスラ以上がよい。該磁石板１は一定間隔で逆方向に磁化され一定周期長の磁石列が得られる。電子線照射時には、減磁と温度上昇が同時に起こるので、このとき該磁石板の保磁力が逆磁場を下回り、逆磁場による着磁が起るものとみられる。

【0018】一方向着磁した該磁石板は逆磁場印加されているので、電子線照射による減磁とそれに伴う温度上昇により、容易に磁化反転を起こし、逆方向に着磁され

る。これを一定間隔で繰り返すことにより、短周期で磁化方向が交互に反転着磁された磁石列を作製する事が出来る。電子線照射による希土類永久磁石の組織変化がないので、反転領域の磁気特性の変化も無く問題はない。このようにして作製された磁石列を複数個組み合わせる事により、短周期長の挿入光源を作製する事が出来る。

【００１９】本発明に用いられる希土類永久磁石板は、式 R(FeCo)BTで表わされ、ここにRはＹを含むＬａ、Ｃｅ、Ｐｒ、Ｎｄ、Ｓｍ、Ｅｕ、Ｇｄ、Ｔｂ、Ｄｙ、Ｈｏ、Ｅｒ、Ｔｍ、Ｙｂ及びＬｕから選択される１種または２種以上の希土類元素であり、ＴはＡｌ、Ｓｉ、Ｔｉ、Ｖ、Ｃｒ、Ｍｎ、Ｎｉ、Ｃｕ、Ｚｎ、Ｇａ、Ｚｒ、Ｎｂ、Ｍｏ、Ｓｎ、Ｈｆ、Ｔａ、Ｗのうちから選択された NdFeBを主体とする焼結磁石である。

【００２０】本発明の挿入光源は、上述の方法により作製された磁石列を複数個用い、図１に示すように磁化面を相対して配置し、該磁石列間に粒子線が通過するための空隙を設けて成るものである。この挿入光源の直線部分の長さは磁石列の反転周期長によって定まるが、本発明の磁石列の場合はこの周期長を５mm以下のものとすることが出来るので、挿入光源を小型化することが出来るため、これを真空下に配置した真空封止型挿入光源とすることが出来る。

【００２１】

【作用】本発明は個々の磁石の磁化方向が周期的に反転する磁石を配列してなる磁石列の製造方法において、厚み方向に一方向磁化された希土類永久磁石板に逆方向磁場を印加しつつ、該磁石板に放射線を空間的に一定間隔で周期的に照射し該磁石板の照射部位を減磁し、同時に逆磁場を印加し磁化反転させることよりなる磁石列の製造方法、及び該磁石列を用いてなる挿入光源を要旨とするもので、本発明によると挿入光源を小型化出来るとするものである。

【００２２】

【実施例】以下実施例について本発明を述べる。

実施例１

粉末焼結法により作製した50mm巾の NdFeB系磁石を着磁した。この NdFeB焼結磁石の磁気特性は、Br=12.5kG 、iHc=18kOe 、(BH)max=37.2MGOeであった。次いで、この着磁磁石を図４に示す磁場が11ｋＧの逆磁場印加用永久磁石磁気回路に磁場の磁界方向と逆にセットし、１mm巾の照射穴よりエネルギーが10ＭｅＶの電子線を60分間２mm間隔で、着磁部に照射したところ図５に示すような磁化パターンを有する、周期長が２mmの磁石を得ることができた。

【００２３】実施例２

実施例１で得られた磁石列を８個用いて、該磁石を４ヶづつ対向させ直線部分が20cmで、周期長２mm、周期数 100の挿入光源を作製した。なお、従来の大気中配置の挿入光源では、周期数 100を実現するには 200～300cm の長さが必要であったので挿入光源の直射部分を従来の1/10以下とすることが出来た。

【００２４】

【発明の効果】本発明の方法により磁化パターンの反転周期が５mm以下とする磁石列が得られるため、これを用いて小型の挿入光源が作製出来る。

【図面の簡単な説明】

【図１】挿入光源の一例を示す図。

【図２】挿入光源で空隙長の長い場合の磁束の流れを示した図。

【図３】（ａ）は電子線照射による消磁機構を示すモデル図。（ｂ）は電子線照射部位の拡大図。

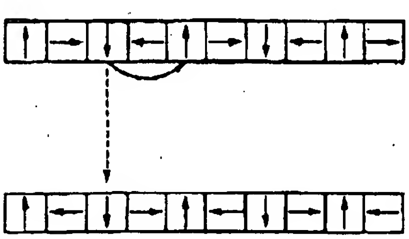
【図４】逆磁場印加永久磁石磁気回路による磁石列の製造方法を示すモデル図。

【図５】本発明の方法により作製された磁石列の磁化パターンの一例を示す図。

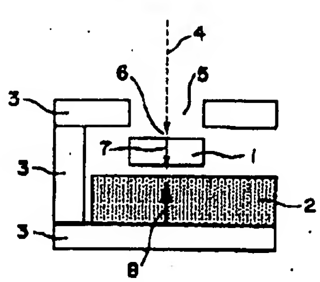
【符号の説明】

１…希土類永久磁石板
２…永久磁石
３…ヨーク
４…電子線
５…隙間
６…空隙
７…着磁方向
８…逆磁場の方向

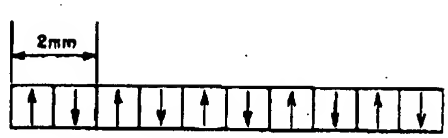
【図２】



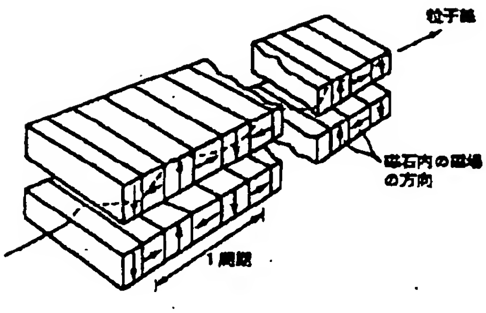
【図４】



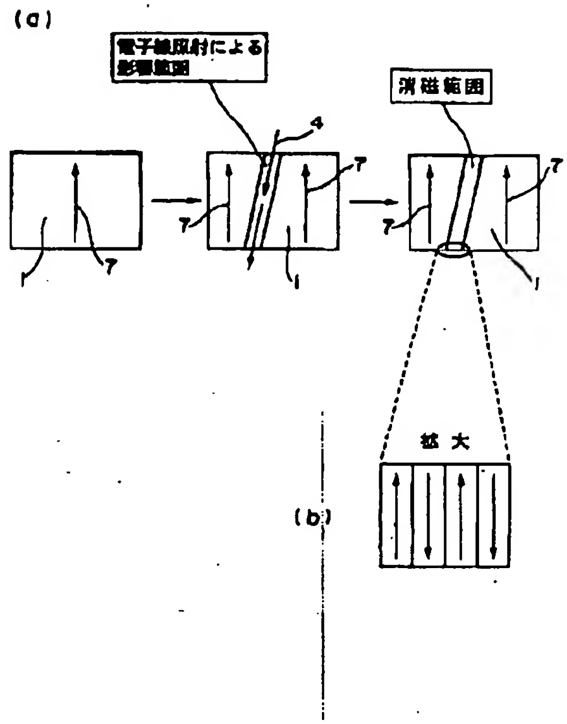
【図５】



【図1】



【図3】



Bibliography

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H05H 13/04
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Epitome

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(57) [Abstract] (******)
[Objects of the Invention] Production of the small insertion light source.
[Elements of the Invention] In the manufacture approach of a magnet train of coming to arrange the magnet which the magnetization direction of each magnet reverses periodically Impressing a backing field to the rare earth permanent magnet plate by which one direction magnetization was carried out in the thickness direction The manufacture approach of the magnet train which consists of irradiating a radiation periodically at fixed spacing spatially at this magnet plate, demagnetizing the exposure part of this magnet plate, and impressing and carrying out flux reversal of the reverse magnetic field to coincidence, and the insertion light source which comes to use this magnet train.

[Translation done.]

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CLAIMS

[Claim(s)]
[Claim 1] The manufacture approach of the magnet train characterized by to irradiate a radiation periodically at fixed spacing spatially at this magnet plate, to demagnetize the exposure part of this magnet plate, and to impress and carry out the flux reversal of the reverse magnetic field to coincidence, impressing a backing field to the rare-earth permanent magnet plate with which the one direction magnetization of the magnetization direction of each magnet was carried out in the thickness direction in the manufacture approach of a magnet train of coming to arrange the magnet reversed periodically.
[Claim 2] The manufacture approach of a magnet train according to claim 1 that a radiation is an electron ray.
[Claim 3] Impression of a backing field The manufacture approach of claim 1 performed by one teslas or more using a NdFeB magnet, or a magnet train given in either of 2.
[Claim 4] The insertion light source characterized by coming to use the magnet train manufactured by one approach of claims 1-3 in the insertion light source which the magnetization direction of each magnet counters and arranges the magnet train which comes to arrange the magnet reversed periodically, and comes to prepare the opening for passage of a corpuscular ray between these magnet trains.
[Claim 5] The insertion light source according to claim 4 whose cycle length of reversal of the magnetization direction of a magnet train is 5mm or less.
[Claim 6] Claim 4 which comes to arrange this magnet train under a vacuum, or the insertion light source given in either of 5.

[Translation done.]

2. **** shows the word which can not be translated.
3. In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the insertion light source which comes to use the manufacture approach of a magnet train, and this magnet train.
[0002]
[Description of the Prior Art] The insertion light source which consists of a permanent magnet or a permanent magnet, and magnetic material (iron and iron cobalt alloy) is inserted in the form whose vacuum chamber the straight-line part of an electron accelerator (or electronic storage rings) pinches, and generates the periodic magnetic field of the letter of a sign all over the opening between magnet trains (refer to drawing 1). The high-speed electron which turns around the inside of an accelerator performs meandering movement by this periodic magnetic field, and produces synchrotron orbital radiation from each point moving in a zigzag direction (Halbach, Nuclear Instruments and Method 187, (1981), 109).
[0003] There are wiggler mode and undulator mode with extent of meandering. In wiggler mode, it is superimposed on the synchrotron orbital radiation generated from each point moving in a zigzag direction, and the synchrotron orbital radiation of 1,000 times [10 times to] as high power as the synchrotron orbital radiation from a deviation electromagnet is obtained. On the other hand, the synchrotron orbital radiation generated from each meandering movement in undulator mode interferes, and a light of wiggler light powerful about further 10 to 1,000 times is obtained with a fundamental wave and its high order light. Wiggler mode or undulator mode can be classified according to the parameter called K value. In the case of not more than 1 order or it, K value serves as an undulator, and it becomes a wiggler in K value beyond it.
[0004] Since the synchrotron orbital radiation power by the insertion light source needs to lengthen the bay of an electron accelerator which the big insertion light source of periodicity is desirable as much as possible, and installs the insertion light source for that purpose since it is proportional to magnet periodicity and it needs to enlarge an

accelerator, it has a limitation in respect of a technique and cost.

[0005] In order to make an accelerator small, it is effective to shorten cycle length of the insertion light source. However, when shortening cycle length, opening length must be made short to coincidence. When opening length is large, the magnetic flux which came out of a certain magnetic pole as shown in drawing 2 is for not going in the direction of an opposite magnetic pole (dotted line of drawing 2), but flowing to the direction (continuous line of drawing 2) of a contiguity magnetic pole. One standard of cycle length and opening length is cycle length = opening length. Therefore, when cycle length is 5mm or less, opening length also needs to make it 5mm or less extent. If the vacuum chamber put in between the openings of the insertion light source is narrowed in this way, it becomes high, and it will become impossible to attain a need degree of vacuum, and an impedance will come to cut in long duration to vacuum suction.

[0006] In order to realize short cycle length's insertion light source, the vacuum lock mold insertion light source is devised (Kitamura; Review of Scientific Instrument 63 (1), (1992), and 400). In a vacuum lock mold, since one pair of magnet trains are installed in a vacuum chamber, constraint of degree of vacuum achievement is lost and becomes possible [shortening magnet opening length]. In the case of a vacuum lock mold, opening length cannot necessarily be shortened without limit. As an inhibition factor, although punishment ** of an electronic beam diameter, the impedance of a vacuum system, and magnet magnetic properties, the magnetic field measurement approach, the adjustment approach, etc. are mentioned, the factor especially related to the magnetic properties of a permanent magnet is important.

[0007]

[Problem(s) to be Solved by the Invention] In the insertion light source, it is sintering of a rare earth magnet. Many NdFeB magnets are used, and this type of magnet has high magnetic properties, and is easy to magnetize. Therefore, since it is convenient for generating a high magnetic field all over an opening and there is little dispersion in the property between the magnets by magnetization, it is suitable for realizing precise magnetic field distribution. For this reason, although generally used to the insertion light source, when realizing the insertion light source of a short period, a problem arises. For example, in order to realize cycle length's 5mm or less insertion light source, it has the thickness around 1mm. A NdFeB magnet is required.

[0008] With a NdFeB magnet, production of the magnet of thin meat produces property degradation by processing, although polish processing

and cutting processing realize. Since area/volume ratio becomes large and surface area becomes large relatively, it becomes impossible to disregard processing degradation with a magnet 1mm or less, although processing degradation hardly becomes a problem with the thick magnet more than mm order since area/volume ratio is small.

[0009] Since it is especially superimposed on dispersion in the property by processing degradation by the case where the homogeneity of the magnetic properties of each magnet is required, like the insertion light source in addition to dispersion in the usual magnetic properties, it is a serious problem. Light-gage It is not so effective, although heat-treating after giving magnetic heat treatment and magnetic rare earth metal covering to a magnet is reported in order to ease processing degradation of a NdFeB magnet.

[0010]

[Means for Solving the Problem] This invention is what manufactures short cycle length's magnet train by improvement of the magnetization approach, without performing light-gage processing of a NdFeB magnet, in order to realize short cycle length's insertion light source. This In the manufacture approach of a magnet train of coming to arrange the magnet which the magnetization direction of each magnet reverses periodically Impressing a backing field to the rare earth permanent magnet plate by which one direction magnetization was carried out in the thickness direction Irradiate a radiation periodically at fixed spacing spatially at this magnet plate, and the exposure part of this magnet plate is demagnetized. the manufacture approach of the magnet train characterized by impressing and carrying out flux reversal of the reverse magnetic field to coincidence -- and The magnetization direction of each magnet counters and arranges the pair of a magnet train which comes to arrange the magnet reversed periodically, and let the insertion light source characterized by coming to use this magnet train be a summary in the insertion light source which comes to prepare the opening for passage of a corpuscular ray between these magnet trains.

[0011] Namely, since magnetization of an exposure part can be reversed by inserting the rare earth permanent magnet plate by which one direction magnetization was carried out in the thickness direction all over the magnetic circuit which generates a reverse magnetic field, and irradiating a radiation at this It finds out that the thing of the short cycle length of a magnet train who comes to arrange the magnet which reversed the magnetization direction of each magnet periodically, without carrying out sheet metal magnet processing is realizable. By this The insertion light source of the high periodicity in comparatively

short die length is producible, by using this insertion light source for a small electron accelerator, it became clear that powerful synchrotron orbital radiation could be generated, many things were examined, and this invention was completed.

[0012] This invention processes a rare earth permanent magnet into the thickness below mm unit, and combine it as usual, and it does not constitute the insertion light source, but the big magnet plate which corresponds more than several round term part is produced. It is the main point of this invention by forming flux reversal periodically by demagnetization and reverse magnetic field magnetization to be able to form the magnet train which arranged many small magnets which reversed the magnetization direction periodically, and to produce the insertion light source using this. The main point of the technique for implementation of the insertion light source which has the short cycle length of this invention is a point which demagnetizes periodically those with two, and the rare earth permanent magnet plate which magnetized one uniformly to the one direction at fixed spacing by radiation irradiation, and another is the point of impressing and carrying out flux reversal of the reverse magnetic field to the demagnetized part.

[0013] If demagnetization by radiation irradiation is explained first, demagnetizing a rare earth magnet by a certain kind of radiation irradiation is known. It sinters especially. It is known that it will be easy to demagnetize the rare earth magnet which has a coercive force device of the generation length mold from a nucleus like a NdFeB magnet or a sintering 1-5 mold SmCo magnet by radiation irradiation as compared with a sintering 2-17 mold SmCo magnet. Demagnetization of this rare earth magnet does not necessarily occur with what kind of radiation, either, tends to occur with corpuscular rays, such as a proton, an electron, and a neutron, and hardly occurs through a gamma ray or an X-ray. For example, this invention persons are produced by relativistic high-speed electron beam irradiation. It is announcement] in [Japanese Society for Synchrotron Radiation Research (1993) which reported demagnetization of a NdFeB magnet.

[0014] The device of demagnetization is not clear, although it is not accompanied by organization change of a magnet about the demagnetization effectiveness by electron beam irradiation and it is clear that it is not heat demagnetization according [and] to a temperature rise, either. The demagnetization model qualitatively shown in drawing 3 (a) can be considered. That is, if an electron ray is irradiated at the magnet magnetized in the fixed direction, the exposure part is magnetized in

the mutually different direction, as shown in drawing 3 (b) and a (enlarged drawing), and it is possible that this negates each other and is demagnetized. Thus, since permanent degradation of organization change etc. is not caused by electron beam irradiation, a magnet will be recovered to the original magnetic-flux value, if it re-magnetizes.

[0015] When it was going to demagnetize the magnetized magnet plate partially, in the heat demagnetization by heat impression, for the heat distortion by diffusion of heat, or the anisotropy of coefficient of thermal expansion, the boundary line of a demagnetization field did not fade and only the magnet plate below a certain thickness was able to carry out partial demagnetization for the crack by heat distortion. On the other hand, since demagnetization occurs in a nonthermal process in the case of radiation division electron beam irradiation, the boundary of a demagnetization field and a non-demagnetizing field is clear, and it is possible to demagnetize only a desired field. Of course, although a certain amount of temperature rise occurred by electron beam irradiation, when especially adjusting coercive force, it understood the magnetic properties of an exposure or a magnet plate and that only an electron-beam-irradiation field can be made to demagnetize. Because, since generating heat uniformly by the exposure part rather than a high-speed electron's permeating to the interior of a magnet and also diffusing heat from a front face and electron beam irradiation are given by the repeat exposure of a short-time pulse, substantial irradiation time is short and is for a temperature rise not exceeding 80 degrees C, either. Since a magnetic field can perform position control of an electron ray to a precision, it is easy position control to perform electron beam irradiation at intervals of about 1mm required of short cycle length's insertion light source.

[0016] Thus, the energy intensity of an electron ray required to cause magnetic demagnetization is 5-20MeV preferably that what is necessary is just 1 or more MeVs. When this exceeds 20MeV(s), there is a problem of activation of a magnet ingredient.

[0017] Although reverse magnetic field impression can be performed in the magnetic circuit using an electromagnet, and the pulse magnetic field and permanent magnet by the air cored coil, the whole is made as for it to a compact. A NdFeB system permanent magnet magnetic circuit is desirable. For example, as shown in drawing 4 , the permanent magnet magnetic circuit for the reverse magnetic field impression which consists of a permanent magnet 2 and York 3 is produced, and the magnetization rare earth permanent magnet plate 1 is inserted in an opening 6. An electron ray 4 is irradiated from the direction of the

upper part, and an electron ray 4 is irradiated from a clearance 5 at this magnet plate 1. By moving in either this magnet plate or a permanent magnet magnetic circuit, electron beam irradiation can be performed at fixed spacing under reverse magnetic field impression. In the permanent magnet magnetic circuit which impresses a reverse magnetic field, the magnetic field strength generated in an opening 6 has good one teslas or more. This magnet plate 1 is magnetized by hard flow at fixed spacing, and fixed cycle length's magnet train is acquired. At the time of electron beam irradiation, since demagnetization and a temperature rise happen to coincidence, the coercive force of this magnet plate is less than a reverse magnetic field at this time, and it is expected that magnetization by the reverse magnetic field takes place.
[0018] Since reverse magnetic field impression of this magnet plate that carried out one direction magnetization is carried out, the temperature rise accompanying the demagnetization and it by electron beam irradiation magnetizes flux reversal to a lifting and hard flow easily. By repeating this at fixed spacing, the magnetization direction can produce the magnet train by which reversal magnetization was carried out by turns a short period. Since there is no organization change of the rare earth permanent magnet by electron beam irradiation, there is also no change of the magnetic properties of a reversal field, and it is satisfactory. Thus, by combining two or more produced magnet trains, short cycle length's insertion light source is producible.
[0019] The rare earth permanent magnet plate used for this invention is a formula. It is expressed with R(FeCo) BT. La, Ce, Pr, Nd, Sm, Eu, Gd, Tb in which R contains Y here, They are one sort or two sorts or more of rare earth elements chosen from Dy, Ho, Er, Tm, Yb, and Lu. T was chosen from from among aluminum, Si, Ti, V, Cr, Mn, nickel, Cu, Zn, Ga, Zr, Nb, Mo, Sn, Hf, Ta, and W. It is the sintered magnet which makes NdFeB a subject.
[0020] Using the magnet train produced by the above-mentioned approach two or more, the insertion light source of this invention arranges a magnetization side face to face, as shown in drawing 1 , between these magnet trains, prepares an opening for a corpuscular ray to pass and changes. Although the die length of the straight-line part of this insertion light source becomes settled by the reversal cycle length of a magnet train, since this cycle length can be made into a thing 5mm or less and the insertion light source can be miniaturized, in the case of the magnet train of this invention, it can be made into the vacuum lock mold insertion light source which has arranged this under a vacuum.
[0021]

[Function] In the manufacture approach of a magnet train of coming to arrange the magnet with which the magnetization direction of each magnet reverses this invention periodically Impressing a backing field to the rare earth permanent magnet plate by which one direction magnetization was carried out in the thickness direction It is what makes a summary the insertion light source which comes to use the manufacture approach of the magnet train which consists of irradiating a radiation periodically at fixed spacing spatially at this magnet plate, demagnetizing the exposure part of this magnet plate, and impressing and carrying out flux reversal of the reverse magnetic field to coincidence, and this magnet train. According to this invention, suppose that the insertion light source can be miniaturized.

[0022]

[Example] This invention is described about an example below.

50mm width produced with the example 1 powder sintering process The NdFeB system magnet was magnetized. this -- The magnetic properties of a NdFeB sintered magnet were Br=12.5kG, iHc=18kOe, and (BH) max=37.2MGOe. Subsequently, the magnetic field which shows this magnetization magnet to drawing 4 set to the direction of a field and reverse of a magnetic field in the permanent magnet magnetic circuit for reverse magnetic field impression of 11kG(s), and from the exposure hole of 1mm width, when energy irradiated the electron ray of 10MeV(s) at intervals of 2mm during 60 minutes at the magnetization section, the cycle length who has a magnetization pattern as shown in drawing 5 was able to get the 2mm magnet.

[0023] Using eight magnet trains acquired in the example 2 example 1, this magnet is made to counter four pieces at a time, and a straight-line part is 2mm of cycle length, and periodicity at 20cm. The insertion light source of 100 was produced. in addition -- the insertion light source of the conventional arrangement among atmospheric air -- periodicity 100 -- realizing -- 200-300cm Since die length was required, the direct part of the insertion light source was able to be made or less [conventional] into 1/10.

[0024]

[Effect of the Invention] Since the magnet train which the reversal period of a magnetization pattern sets to 5mm or less by the approach of this invention is acquired, the small insertion light source is producible using this.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] Drawing showing an example of the insertion light source.
[Drawing 2] Drawing having shown the flow of magnetic flux when opening length is long according to the insertion light source.
[Drawing 3] (a) is the model Fig. showing the demagnetization device by electron beam irradiation. (b) is the enlarged drawing of an electron-beam-irradiation part.
[Drawing 4] The model Fig. showing the manufacture approach of the magnet train by the reverse magnetic field impression permanent magnet magnetic circuit.
[Drawing 5] Drawing showing an example of the magnetization pattern of the magnet train produced by the approach of this invention.
[Description of Notations]
1 -- Rare earth permanent magnet plate
2 -- Permanent magnet
3 -- York
4 -- Electron ray
5 -- Clearance
6 -- Opening
7 -- The magnetization direction
8 -- The direction of a reverse magnetic field

[Translation done.]

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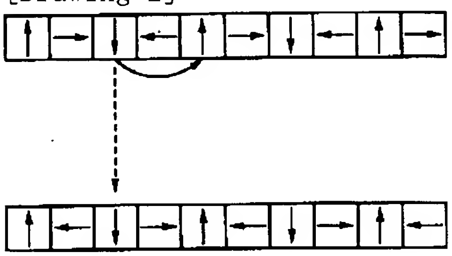
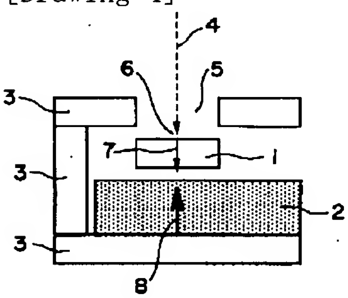
DRAWINGS

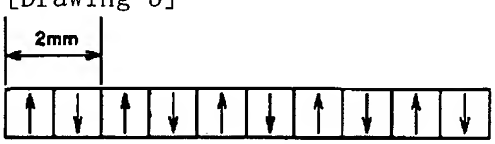
[Drawing 2]



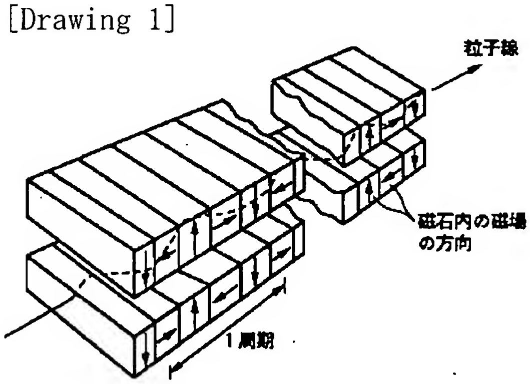
[Drawing 4]



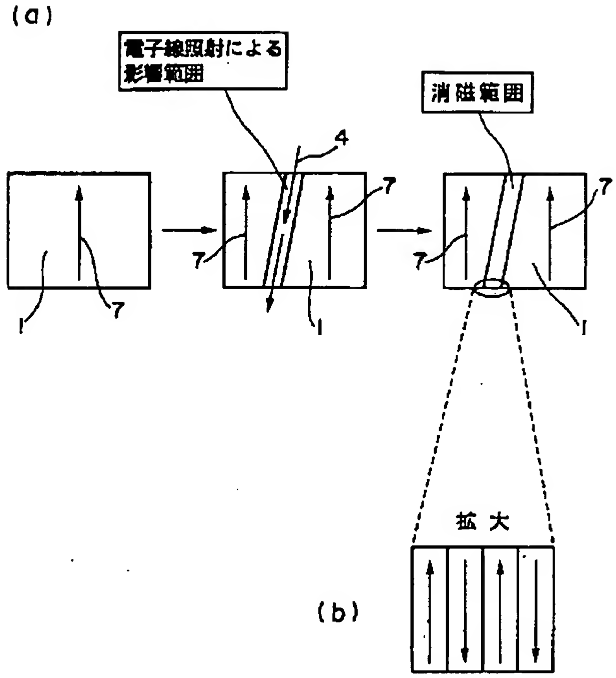
[Drawing 5]



[Drawing 1]



[Drawing 3]



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